

# JOURNAL OF THE EAST AFRICA NATURAL HISTORY SOCIETY AND NATIONAL MUSEUM

---

DECEMBER 1986

VOLUME 76, No. 189

---

## OBSERVATIONS ON *SALVINIA* AND ITS ENVIRONMENT AT LAKE NAIVASHA (KENYA)

Nils Tarras-Wahlberg

Nydala, 570 03 Vrigstad, Sweden

### ABSTRACT

Lake Naivasha is a freshwater lake in the Rift Valley of Kenya. It was infested in the 1960s by the floating fern *Salvinia molesta* Mitchell. This fern is indigenous to Brazil where it is apparently harmless. At lake Naivasha, as in several other inland waters of the tropical Old World, it is capable of an explosive population increase, and it can occupy the surface of calm nutrient-rich waters very quickly. By forming a surface-mat, it stops sunlight from reaching submerged plants and so it kills the submerged vegetation. This has resulted in serious setbacks to the local fishing industry.

It is shown that in nutrient-rich waters young *Salvinia* has a doubling time of 4.5 days. Optimal growing conditions exist near Papyrus stands. Old mats of *Salvinia* may be invaded by vascular plants, and so a formation of sudd may start.

### INTRODUCTION

The project to study *Salvinia*, of which this paper is one of the results, was carried out in 1974-75 and was followed up during a brief period in 1981. The project was sponsored by SIDA.

Lake Naivasha is situated 100 km NW of Nairobi at an altitude of 1890 m. Its surface area is 160 km<sup>2</sup>. It is a relatively shallow lake of recent geological origin, surrounded by extinct or dormant volcanoes. Two major rivers, Malewa and Gilgil, drain into the lake, bringing rainwater from the Nyandarua (Aberdare) Range. This is an important factor in keeping the lake fresh as evaporation from the lake is more than twice as much as the local rainfall (Ase 1983). At the northern side of the lake these rivers have formed the 11.7 km<sup>2</sup> large North Swamp. As shown by Fig. 1 there are several other fringing, floating swamps on the lake. These were formed during periods of low water when papyrus (*Cyperus papyrus* L.) started to grow on the exposed mud at the shore. The following periods of high water changed the cultivated land near the shore into a shallow part of the lake, now separated from open water by papyrus. A lagoon was thus formed with optimal growing conditions for submerged and floating vegetation. In 1975 a waterlily, *Nymphaea coerulea* Savigny was dominant; in 1985, during a brief visit to the lake, only eight flowers of this species were observed.

### Survey methods

For the survey, the following instruments were used: two battery-powered pH and electrical conductivity meters (Esselte 1973 model), an albedo-meter (Kipp & Zoonen model), a portable oxygen meter (Beckman Fieldlab) and during the last period of work a Hach Fieldlab with a spectrophotometer (Dr-El 2).

The growth rate of *Salvinia* in its natural environment was measured inside floating culture-cages of various design. The arrangement with floats proved to be the best in situations where the water suddenly rises after heavy rains.

### History of *Salvinia* on Lake Naivasha

The occurrence of *Salvinia* on Lake Naivasha is a relatively recent phenomenon. In the early 1960s it was introduced (certainly by man) to the lake and in 1964 it covered 60 ha at the eastern part of the lake. Steps

---

for control were organized, resulting in spraying with the herbicide paraquat and in mechanical removal by volunteers and landowners. In the late 1960s eradication was considered to have been achieved, but isolated individuals were alive inside the northern swamp, and started to spread into the lagoon inside the swamp. In October 1970 a strong wind from the north broke the palisade of papyrus and *Salvinia* was spread all over the lake (Gaudet 1976). *Salvinia* infestation of the spawning grounds of *Tilapia* fish caused concern at the Fisheries Department, as the fishing industry faced a severe setback.

#### Taxonomy of *Salvinia*

Mitchell (1973) described the new species *Salvinia molesta* from inland waters in Africa, Indonesia, Australia and from a pond in Rio de Janeiro, Brazil. Before that, the "African pile" was believed to be *S. auriculata* Aubl. Mitchell suggested that the new species was a hybrid between *S. biloba* and *S. auriculata*, also found in the same pond. It has been shown subsequently (Forno & Harley 1979, Forno 1983) that *S. molesta* grows naturally in several districts of South America and is one of four closely related species forming the *S. auriculata* group. The growth of *S. molesta* in Brazil seems to be very modest and creates no problems. Forno and Harley suggest that the reason for this is the presence of natural enemies. *Salvinia molesta*, from here on just called *Salvinia*, is probably a hybrid as it is sterile. It seems to show hybrid vigour and is able to multiply by means of vegetative propagation. Today it has a worldwide distribution, and the clone will possibly number billions of individuals! It is causing much harm and has therefore been in focus nearly as much as *Eichhornia crassipes* Mart., the water hyacinth. Actions for the control of *Salvinia* have been expensive and nearly always without lasting results, as has been the case at Lake Naivasha.

#### Life-cycle of *Salvinia* at Lake Naivasha.

Mitchell (1969, 1974, 1976) has published findings on the autecology of *Salvinia*. He distinguishes three stages of growth:

- 1) The primary invading form with small leaves, not exceeding 1.5 cm in width, floating on the water surface.
- 2) The open water colonizing form with long internodes and keeled leaves of about 2 cm width.
- 3) The mat form of the plant with short internodes and of a compressed shape. This form has leaves of up to 6 cm in width, which are folded upwards and have lost direct contact with the water. Sporocarps are present, but sterile.

All three forms have a submerged leaf at each node. This leaf has the shape of a root and its function is nutrient absorption and stabilization. The submerged parts of *Salvinia* tend to elongate when nitrogen is deficient (Gaudet 1973).

At low water in 1974-75, many single *Salvinia* plants were transported by the NE monsoon to the western side of the lake and got stranded. Others died on the open lake where conditions of waves together with a superabundance of oxygen proved fatal. These effects were reported by Kariuki (1974, typewritten report at KSTC). When drifting *Salvinia* plants became stranded on wet exposed mud in the shade of papyrus they started to disintegrate. Old plants were however able to start a new generation by means of extensive budding in the mud. Mitchell (1969) has shown that the number of lateral buds is dependent on the amount of nitrogen available, i.e., the more nitrogen the more buds. Gaudet (1976) laid stress upon the great importance of the exposed mud being extremely rich in nutrients, and especially in nitrogen, for the growing new generation of *Salvinia*. At the end of the long rains in April the reflooding of the lake will add still more nutrients. These are washed out from the mud at the shore as the process of oxydation has set them free during the process of exposure and drying. Nutrients may also be brought in from fields nearby, where hippos and cattle have deposited their dung. Fertilized farmlands may also supply additional nutrients.

In the nutrient-rich shallow water young *Salvinia* will grow and start the explosive population increase which is well-known from laboratory experiments by Gaudet (1973) and Mitchell & Tur (1976). The *Salvinia* from Lake Naivasha is rich in mineral salts which is indicated by its use as a fertilizer (Gaudet 1973). The same authority suggests *Salvinia* as an agent for the removal of nutrients from waters. Accordingly it can be used for the reversal of eutrophication in recipient water bodies (Toerien et al. 1983). The young *Salvinia* will rapidly spread over the water surface. In the shade of papyrus *Salvinia* will sometimes associate with *Ricciocarpus natans* L.

Experiments arranged at Fishermans Camp (see Fig. 1) in cages, have shown that young *Salvinia* have a speed of growth which is close to what was observed in laboratory conditions such as those of Gaudet (1973) and Mitchell & Tur (1976). The result of the experiments is presented in fig. 2. This result was

observed in a cage with 50% cover after heavy rains. It is assumed that an increased supply of nutrients was caused by these rains.

One can suggest that the growth of *Salvinia* is density-dependent. The explanation for this would be competition for nutrients or for space. In the laboratory, under optimal conditions, Gaudet (1973) using *Salvinia* from Lake Naivasha found a weight doubling time of 4.6 days. Mitchell & Tur (1976) found a similar result in the laboratory, but under field conditions in Lake Kariba the growth rate was much more modest (Mitchell & Tur 1976).

While growing in the natural environment the plants float into deeper water with less shade. The agent for transportation is either rising water, wind or man. The growing *Salvinia* now passes into the third phase and mats will develop. Its weight (wet weight, gravity water removed by centrifuging) will now exceed 10 kg/m<sup>2</sup>. After the formation of mats growth is very slow. In the midst of the wide mats an additional increase of weight per unit of area is probably entirely dependent on an increase of nutrients which may be conveyed by hippos, currents or man.

Agitation may set *Salvinia* afloat to reach new localities. Infestation may easily occur where submerged vegetation is thick and close to the surface. This seems to be a normal condition where *Ceratophyllum demersum* is growing. This locality will then be taken over by *Salvinia* which can make the *Ceratophyllum* turn yellow and die because of its shading effect. Photosynthesis and productivity will thus occur in the layer just above the water surface. In places where the nutrient conditions are good the old *Salvinia* can live for a very long time, growing at one end, dying at the other. The optimal conditions for such old *Salvinia* mats may be found where slightly moving water is transporting nutrients to the submerged leaves. The river outlets into the lake provide such an environment. As was shown by Gaudet (1979) these areas will also produce additional nitrogen by fixation within the papyrus swamps. The nitrogen fixed is deposited in the sludge below the swamp or directly added to the lake through decomposition, which is as high as a yearly loss of one-third of the total biomass of the papyrus.

The nitrogen-rich sludge below the swamp shows a seasonal pattern of being flushed into the lake. In this way *Salvinia* is nourished as well as nursed by the papyrus at Lake Naivasha. The two plants are closely associated. At the river outlets and outside the north papyrus swamp huge *Salvinia* localities were found at places where irrigation pumps created currents towards the land. Near such places one can also expect nutrient input from fertilizers. Places where hippos are frequent also make good growing spots for *Salvinia* (Diedrichs 1976).

#### **The *Salvinia* sudd of Lake Naivasha**

The term sudd derives from the Sudd swamp on the upper White Nile, where floating papyrus islands are big and firm enough to carry both man and cattle (Beadle 1974). The term sudd has also been used to denote floating islands in general when they are made of dense vegetation. Mitchell (1969) uses the name sudd for the old mats of *Salvinia* which are colonized by vascular plants on Lake Kariba. Gaudet (1973) claims that sudd is absent on Lake Naivasha whilst Tarras-Wahlberg (1984) uses the term mini-sudd for floating islands of *Salvinia* and others plants which were found to be the environment of a new species of *Oribatei* (mites or *Acari*). Sudd was certainly present on Lake Naivasha in 1974 and 1981 on the large papyrus-fringed lagoon outside the mouth of the river Gilgil. According to Mr. Hopcraft, a land-owner living near the place where the infestation of *Salvinia* started, it occurred here as early as the 1960s. The *Salvinia* in that region of the lake has, after the early failure of control, been allowed to grow nearly undisturbed, in which respect that part of the lake is unique. The large mass of *Salvinia* outside the Malewa river mouth was sprayed with herbicide at the end of the 1970s and disappeared completely after the rise of the water level. Hopcraft's lagoon can still, and actually should be, researched! As it is very difficult to penetrate Hopcraft's lagoon, preliminary research was started instead at Mennell's lagoon, the wide lagoon on the NW side of the lake.

*Salvinia* got into this lagoon in the 1970s through a man-made canal through the fringing papyrus swamp. At this lagoon, which had quite a different shape in 1981 compared to that of 1975, it was possible to find sudd formations of different ages and constitution.

The *Salvinia* sudd is composed of the remnants of several generations of *Salvinia* which have succeeded each other and which have interweaved into a permanent turf. At Mennell's Lagoon in 1981 the sudd was 30-40 cm thick, consisting of dead *Salvinia* at the bottom and living *Salvinia* on top; this mat was invaded by the common vascular plants of the shore. The pioneer of this invasion was *Hydrocotyle ranunculoides* L., being the only plant apart from *Salvinia* in most places on the sudd. Older sudd mats also had the following species: *Cyperus* sp., *Sphaeranthus suaveolens* (Forssk.) DC, *Senecio moorei* RE Fries, *Ludwigia stolonifera* (Guill. & Perr.) Raven and *Gnaphalium* sp.

### Animals related to *Salvinia*

A species of *Oribatei* (Mites or *Acari*), *Hydrozetes lemnae* Coggi is very common in young and mature mats of *Salvinia*. This is an amphibious species of mite with a world-wide distribution. It has been reported to occur on *Salvinia molesta* in Florida, USA (Krantz & Baker 1982). When the *Salvinia* mats change into sudd this species disappears and is replaced by another oribatid mite, *Trimalconothrus scimitarum*, which was described as a new species in a separate paper (Tarras-Wahlberg 1984). This species is also common among roots of papyrus on Lake Naivasha. *Rhopalosiphon nymphae* was a numerous and conspicuous aphid on *Salvinia* outside Mennell's Lagoon in 1981. As a potential vector to a still unknown virus disease this aphid might be of importance for biological control of *Salvinia* in the future.

Earthworms are frequent in older mats of *Salvinia* and they seem to compose the only detected suitable food for birds feeding there. Among the birds the Lily-Trotter and the Long-toed Lapwing are restricted to floating vegetation for their breeding. As has been pointed out earlier (Tarras-Wahlberg 1981) the *Salvinia* areas of Lake Naivasha can apparently bear a denser population of the Lily-Trotter than the earlier Water-lily vegetation. The first breeding record of the Long-toed Lapwing for Lake Naivasha was on *Salvinia* in 1975.

Other species of birds observed on *Salvinia* come there for shelter and food. The African clawed toad, *Xenopus mulleri* Peters, both as adult and as tadpole, thrives below *Salvinia* and is taken by the Squacco Heron as it comes to the surface for breathing. Hadada Ibis were seen taking earthworms. Crayfish (*Procambarus clarkii*) are caught by the African Fish Eagle as well as by others when they occur near a *Salvinia* mat. Nymphs of dragonflies are taken by the Malachite Kingfisher.

The following records of birds made at two different *Salvinia* localities are characteristic of its richness in species and individuals.

1. Wide *Salvinia* mat outside Malewa River Mouth, 15.11.1974  
Observer: Evert Bengtsson  
Lily-trotter 30, Long-toed Lapwing 38, Blacksmith Plover 15, Wood Sandpiper 50, Greenshank 10, Marsh Sandpiper 10, Ruffs and Reeves 150, Curlew Sandpiper 5, Little Stint 300, Ringed Plover 15, Glossy Ibis 5, Saddle-bill Stork 1, Moorhen 15, Black Crake 4, White Pelican 6, Pink-backed Pelican 10, African Skimmer 2, White-winged black Tern 50, Whiskered Tern 8.
2. Wide *Salvinia* mat outside Gilgil River mouth, 27.02.1975  
Observer: Nils Tarras-Wahlberg  
Lily-trotter 2, Long-toed Lapwing 6, Blacksmith Plover 2, Greenshank 1, Little Stint 300, Sacred Ibis 3, Glossy Ibis 122, Hadada Ibis 2, Little Egret 25, Yellow-billed Egret 2, Grey Heron 1, Squacco Heron 5, Purple Gallinule 2, Black Crake 3, Egyptian Goose 2, Yellow-billed Duck 10, Little Grebe 1, Pink-backed Pelican 1, Woodland Kingfisher 2.

These lists of birds include a great number of migrants from Northern Europe. A possibility exists that they transport minute animals from the mires there to Tropical Africa. A few mysterious findings of single individuals of *Oribatei* (*Nothrus pratensis* Sell., *Tectocephus velatus* Mich.) from *Salvinia* outside the northern swamp might be explained this way, as they are both typical species of Scandinavian mires!

The rich bird-life on *Salvinia* at Lake Naivasha is a positive aspect of an otherwise negative situation. In general animal life in connection with *Salvinia* is still a neglected subject.

### Abiotic environmental factors

A limited collection of environmental chemical and physical data was made, and the results are presented here. Publications by Gaudet (1973, 1977, 1979) give further information.

In 1975 large mats of *Salvinia* occupied the lake surface in front of the river-mouths at the NE side of the lake. Apparently conditions there were optimal. On an albedometer very high readings of solar radiation were recorded, as well as an albedo for *Salvinia* of 0.15-0.20.

Later disturbance by hippos forced me to move the instrument to the Fisheries Department inside the Crescent Island. Records were obtained of the global radiation for the first six months of 1975. Figure 3 gives the mean readings of every hour during the day over the whole observation period, and includes the positive and negative standard deviations. The shape of the curve reflects the usual weather pattern: a sunny morning, followed by soaring cumulus clouds at noon; towards the afternoon, thunderstorms are normal. Wind may then come from any direction as indicated by the wind compass in Fig. 1. The mean

daily global radiation for one cm<sup>2</sup> at Lake Naivasha was  $577 \pm 202$  gram calories. The radiation naturally influences the temperature of the *Salvinia* mats. Room & Derr (1983) have made an interesting study of the microclimate in a *Salvinia* mat in Australia. In general the temperature of the mat was higher than that of the air above it. *Salvinia* was also shown to be able to self-regulate its temperature. A detailed study of the microclimate must precede any transfer of organisms for control of *Salvinia* from one area to another (Room & Derr, 1983).

Old and dense mats of *Salvinia* allow very little light to penetrate them. Mitchell (1969) gives the record 0 (nil) for mats at Lake Kariba, Zambia. A few measurements made at Lake Naivasha in January 1975 also show no light penetrating to the water surface below the mat. Because of this, no photosynthesis can occur. A few oxygen measurements from below *Salvinia* mats at Lake Naivasha show very low values.

It is obvious that a scarcity or lack of oxygen strongly influences the ecology of the Lake within the *Salvinia* areas. Anaerobic conditions like this are well-known from tropical floating swamps. Gaudet (1979) reports on his studies on the northern papyrus swamp at Lake Naivasha. As the vast *Salvinia* mats during the period of his observations (1974-75) were immediately outside his research area, a lot of relevant information on *Salvinia* ecology can be deduced from his studies.

Two points relating to the quality and quantity of the water of Lake Naivasha are of interest:

- fluctuations of water level, i.e. the relation between inflow and evaporation of water
- the salinity of the water as indicated by records of electrical conductivity and pH.

As regards the fluctuations of water-level, it can be regarded as certain that seepage out of the lake occurs (see Ase 1983). Gaudet (1979) has studied the fluctuation of the water level and its impact on the vegetation of the lake. He has pointed out the great importance of the fluctuations on the growth of papyrus. As *Salvinia* is dependent on papyrus, it too is affected by the fluctuations.

In 1974 the water level was very low, and the lake, at least on its eastern edge, had nearly turned into a soda lake. The pH was about 10, and the electrical conductivity was as high as 1000 microS (readings taken at Crescent Island, 17.09.1974). At the same time the lesser Flamingo was seen in hundreds near Naivasha town, apparently feeding in the shallow water. This low water exposed large areas of wet mud, on which papyrus (and consequently *Salvinia*) established itself. When the water was at its lowest level, no *Salvinia* survived in the culture cages inside Crescent Island, presumably because of the high water pH and high electrical conductivity values. Fig. 4 shows the great variation of these values in both space and time, recorded over a 10-day period at the end of 1974. The most likely factor behind this variation is the photosynthetic action of the planktonic algae which consume nutrients and carbon, causing electrical conductivity to increase and the pH to decrease. This is most likely to occur at sampling station 4.

Another possible reason for these abrupt changes could be the underground inflow of salty water, postulated by Thomson and Dodson (see Ase 1983). A core taken by Ase at the Lake to the north of Hell's Gate revealed several porous zones. These parts of the core also became coated with salt crystals when they dried (Ase, pers. comm.). An underground seepage into the lake might well be salty.

In 1974 when the lake was at its lowest level the author observed swirls from the bottom in the northeastern part of the lake. Some months later no swirls were seen but water samples from the same area showed a pH of 9.8 and an electrical conductivity of 500 microS. Probably an underground supply of salty water only happens when the water level is extremely low. However, such a salty upwell may explain the extreme values of pH and electrical conductivity recorded from the northeastern part of the lake. The capricious values recorded may well be explained by the variable wind-directions. Crescent Island is the rim of an old crater, which continues below the surface of the water. In situations of very low water the inside of the crater will form a separate lake, which will quickly turn into a soda lake through evaporation. This would raise the values of pH and electrical conductivity.

One more explanation has to be discussed. Close to the lake shore near Naivasha town a vegetable dehydration plant has been built. In 1975 the spill water from the factory was channelled into the maize fields as fertilizer, but before this was done the whole amount went into the lake, via the shore. Measurements of the electrical conductivity of this effluent showed a value of 1500 microS. During the same period as the very high pH and electrical conductivity were registered in the lake, the values of samples from Gilgil and Malewa Rivers were low (Gilgil R. 75 microS, Malewa R. 50 microS on 31.10.1975). Daily samples taken for 30 consecutive days from the Malewa River at a point near the outlet gave a mean value of 48.8 microS.

pH values for this study were taken on many occasions. The *Salvinia* areas of the lake had a mean pH of 7.1, those areas without *Salvinia* a mean of 8.5. This difference can probably be explained by the lack of photosynthesis below the *Salvinia*, as no removal of CO<sub>2</sub> and consequent decrease of pH can occur.

## Synopsis:

In 1974-75, during the end of a period of very low water, values of electrical conductivity and pH in Lake Naivasha were higher than normal, and showed great variations in time and space. *Salvinia* areas of the Lake gave lower values of these factors, at least where the growth was luxuriant. The absence of *Salvinia* from waters inside Crescent Island is probably related to the high values of pH and electrical conductivity there.

## ACKNOWLEDGEMENTS

I wish to thank the following for invaluable help during this study: The staff of the Kenya Science Teachers College, Nairobi; the employees of the Fisheries Department; the members of the Riparian Owners Association, especially the late Mr. Roger Mennell. Mr. John Kosodo assisted during most of the field work, and did all research on water chemistry near Crescent Island. Lars-Erik Ase made valuable criticism on the manuscript.

## REFERENCES

- Ase, L.E. 1983. Lake Naivasha — en sotsvattensjö i Kenyas Rift Valley — och dess vattenstandsobservationer. Svensk Geografisk Årsbok 58: 157-169.
- Beadle, L.C. 1974. The inland waters of tropical Africa. London.
- Diedrichs, J. 1976. Untersuchungen zur Ökologie des Flussperdes. Zoologisches Institut, Braunschweig.
- Forno, I.W. & Harley, K.L.S. 1979. The occurrence of *Salvinia molesta* in Brazil. Aquatic Botany 6: 185-187.
- Forno, I.W. 1983. Native distribution of the *Salvinia auriculata* complex and keys to species identification. Aquatic Botany 17: 71-83.
- Gaudet, J.J. 1973. Growth of a floating aquatic weed, *Salvinia*, under standard conditions. Hydrobiologia 41: 77-106.
- 1976. *Salvinia* infestation on Lake Naivasha in East Africa (Kenya). UNESCO Regional Seminar on noxious aquatic vegetation in the Tropics and Subtropics: 193-209. Junk, the Hague.
- 1977. Natural drawdown on Lake Naivasha (Kenya) and the origin of papyrus swamps. Aquatic Botany 3: 1, 47.
- 1979. Seasonal changes in nutrients in a tropical swamp: North Swamp, Lake Naivasha, Kenya. Journal of Ecology 67: 953-981.
- Krantz, G.W. & Baker, G.T. 1982. Observations on the plastron mechanism of *Hydrozetes* sp. Acarologia t. 23, fasc. 3: 272-276.
- Mitchell, D.S. 1969. The ecology of vascular hydrophytes on Lake Kariba. Hydrobiologia 34: 448-465.
- 1973. *Salvinia molesta* sp. nov. Br. Fern Gaz. 10: 251-252.
- 1974. The effects of excessive aquatic plant populations. UNESCO, Paris.
- & Tur, N.M. 1976. The rate of growth of *Salvinia molesta* (*S. auriculata* Auct.) in laboratory and natural conditions. J. Appl. Ecol. 12: 213-225.
- Room, P.M. & Derr, J.D. 1983. Temperatures experienced by the floating weed *Salvinia molesta* Mitchell and their prediction from meteorological data. Aquatic Botany 16: 91-103.
- Tarras-Wahlberg, N. 1981. Fägel, flodhast och flytande färsot på Naivasha-sjön i Kenya. Fauna och Flora 76: 157-164.
- 1984. *Trimalaconothrus scimitarum* nov. sp., an aquatic oribatid mite from Lake Naivasha, Kenya. Inter. J. Acarology 11, 7: 17-21.
- Toerien, D.F. P.R. Finlayson, C.M. Mitchell, D.S. & Weerts, P.G.J. 1983. Growth models for *Salvinia molesta*. Aquatic Botany 16: 173-179.

Received January 1984

Editors: H.J. Beentje, J.J. Hebrard

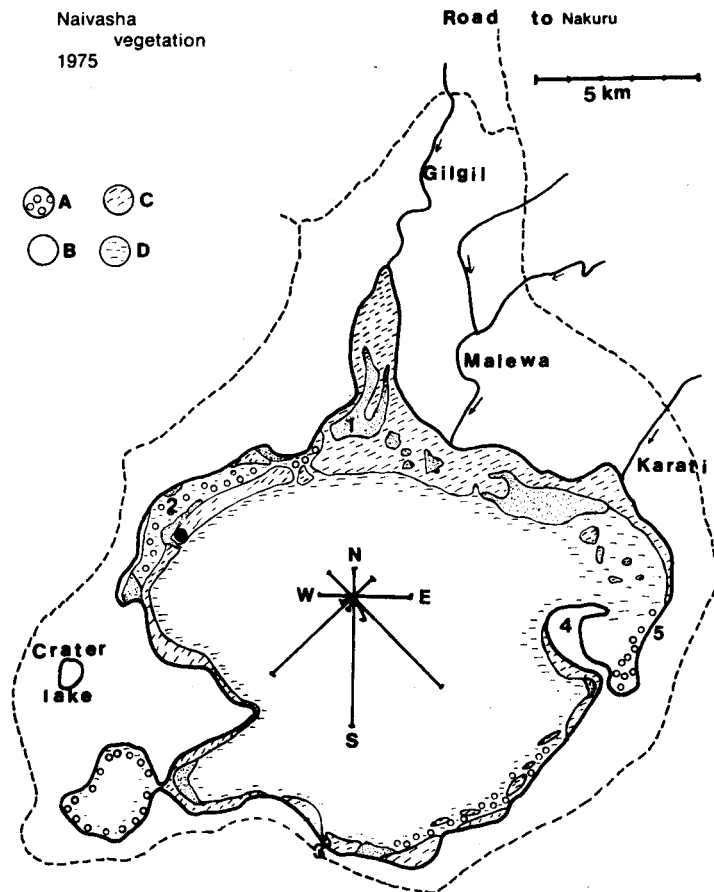


Fig. 1 Lake Naivasha, vegetation in 1975 and the main localities mentioned in the text. A - water lilies, B - *Salvinia*, C - *Papyrus*, D - submerged vegetation. 1 - Hopcrafts's lagoon, 2 - Mennells lagoon, 3 - Fishermans' Camp, 4 - Crescent Island, 5 - Fisheries' Department.

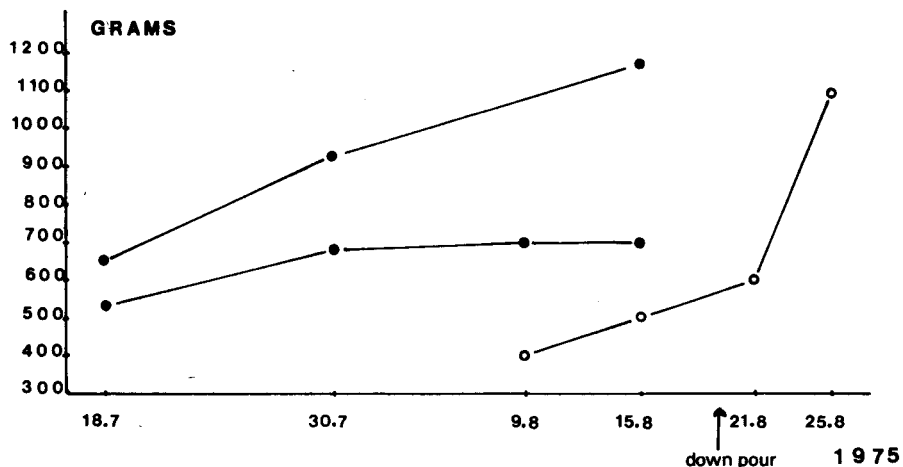


Fig. 2 Weight of *Salvinia* (wetweight - gravity water removed by centrifuging) during a period in 1975 at the shore of Fisherman's Camp. Notice the remarkable rate of growth after a downpour, which is supposed to have brought nutrients to the place of experiment.

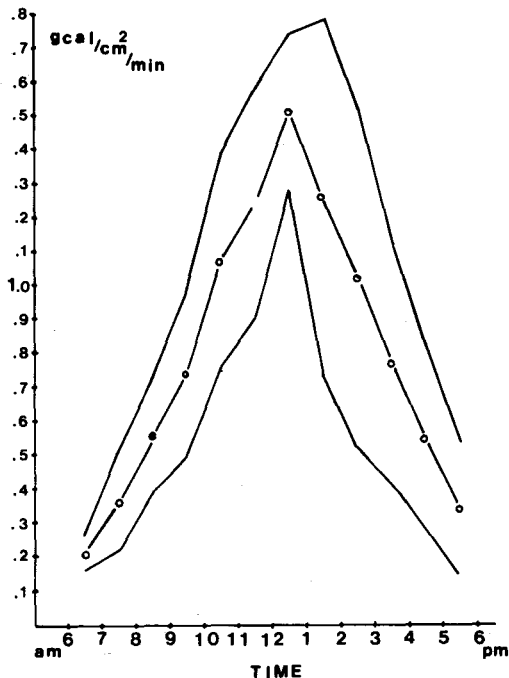


Fig. 3 Global radiation at the Fisheries' Department inside Crescent Island during the first half of 1975. The graph shows the mean values of each hour during the period with the standard deviations included at the adjacent curves. Notice the high deviations from noon onwards which are caused by the random occurrence of cumulus and cumulonimbus clouds.

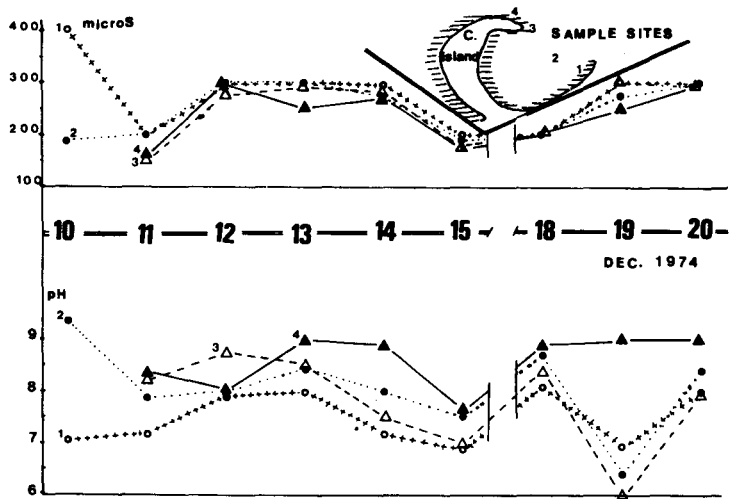


Fig. 4 Short-period variations of pH and electrical conductivity at 4 stations near Crescent Island during a period at the end of 1974.

hour	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
number of records	11	34	57	31	39	53	33	44	34	59	33	70
mean gcal/cm <sup>2</sup> /min	0.21	0.36	0.56	0.74	1.07	1.24	1.51	1.26	1.02	0.77	0.54	0.34
standard error ±	0.10	0.10	0.14	0.16	0.24	0.31	0.34	0.23	0.53	0.50	0.35	0.26
	0.10										0.26	0.19